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Evolution of Shutdown Chemistry During Refueling Outage 9 in Yonggwang Unit 4

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1. Introduction

Reactor coolant shutdown chemistry seeks to solubilize corrosion products generated during the operating cycle and remove them via demineralization. This process is induced by proper control of chemistry during the shutdown process and releases elevated levels of radioactivity into the bulk coolant. The solubilization of these radionuclides is significant in that it makes it easier for the radionuclides to be transported to the demineralizer, thereby minimizing the activation of deposited corrosion products and the release of already activated species. For many years, PWR plants have sought to optimize the interplay between shutdown chemistry and plant equipment, often modifying both. Numerous strategies have been developed to reduce radiation fields, personnel exposure, and outage durations.

Optimization of shutdown chemistry practices becomes increasingly important due to the current industry interest in safety and plant availability. This paper deals with the evaluation results of shutdown chemistry at Yonggwang unit 4 Refueling 9 for optimizing plant practices. The data gathered by electronic dosimeters and ISOCS (In-Situ Object Counting System) device were also discussed in this paper.

2. Shutdown Chemistry Evaluation

2.1 Shutdown Chemistry during R9

Yonggwang decreased power at 3 % per hour for R9 starting 1/4/07. On January 4 at 07:00 the turbine was tripped, and the plant was in Mode 3 at 08:10. Borations between 07:05 and 17:50 increased boron concentration of primary coolant to 2,500 ppm. A small particulate release of Co-58 occurred immediately after rod drop test, which was performed at 14:39 on January 4 (Figure 1). After the addition of hydrogen peroxide for the controlled solubilisation of crud, the Co-58 increased to 1.82 uCi/mL.

Figure 2 shows the hydrogen concentration relative to pHt and pH_N during R9. Note that the pHt was lowered very rapidly, and the hydrogen was also decreased to about 10 cc/kg during boration. However, the hydrogen concentration was increased up to 28 cc/kg during cooldown due to re-dissolution of hydrogen from the gas space of the VCT (Volume Control Tank) and pressurizer. The cover gas on the VCT was switched to nitrogen after entering Mode 4.

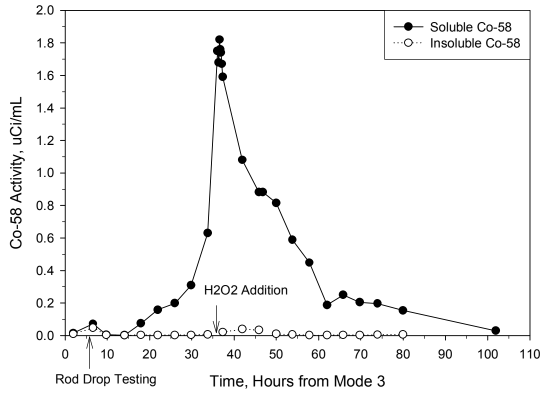

Figure 1. Soluble vs. insoluble Co-58 during R9

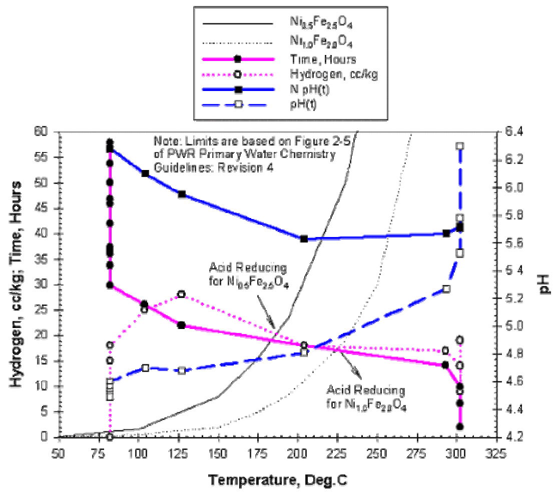

Figure 2. Yonggwang unit 4 R9 acid-reducing condition

Figure 2 also shows acid-reducing conditions for R9. Generally, acid-reducing conditions were maintained to facilitate nickel ferrite decomposition. Approximately 17-18 hours were allowed to decompose $Ni_{1.0}Fe_{2.0}O_4$, and approximately 16 hours to decompose $Ni_{0.5}Fe_{2.5}O_4$. These conditions were appropriate for promoting iron solubility and nickel ferrite decomposition.

2.2 Electronic Dosimeter Dose Rates

Electronic dosimeters were used to define the effect of shutdown chemistry evolutions by installing them at numerous locations in the containment building (including hot leg and suction leg etc.) and obtaining data during or after various stages of the process. In figure 3, the dose rate measurement data on primary component are shown.

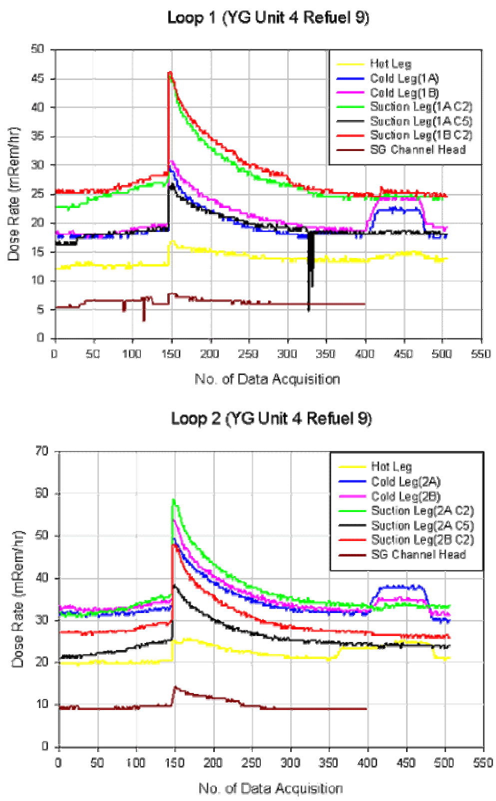

Figure 3. Dose rates distribution on primary components

Hydrogen peroxide addition induced a large increase of dose rates caused by elevated soluble radiocobalt concentration in the coolant. The extent of dose rates increase may be different depending on the coolant Co-58 concentration and the thickness of the piping. From figure 4, it is highly recommended to establish ALARA plan to restrict access to elevated dose areas, especially in the vicinity of the suction leg (between the steam generator and the RCP) during peroxide addition. The dose rates were returned to a initial value as Co-58 was cleaned up by the letdown ion exchanger.

2.3 Gamma Spectroscopy Measurements

In order to evaluate the shutdown impact on crud behavior, the activities deposited in the steam generator channel head (especially SG #2 cold leg side) have been measured using a portable Canberra gamma spectroscopy device (ISOCS). The measurements were taken on between January 4 and January 7.

Figure 4 shows the variation in the Co-58 and Co-60 activities compared with the initial measurement value. Note that a visible reduction in the Co-58 and Co-60 activities deposited on the steam generator channel head during shutdown evolutions has never been observed, which means that plant decontamination does not occur during shutdown chemistry.

Judging from this figure, we inferred that the primary purpose of shutdown chemistry should be problem avoidance such as increased radiation fields and extended outage schedules resulting from uncontrolled particulate releases (namely, crud burst).

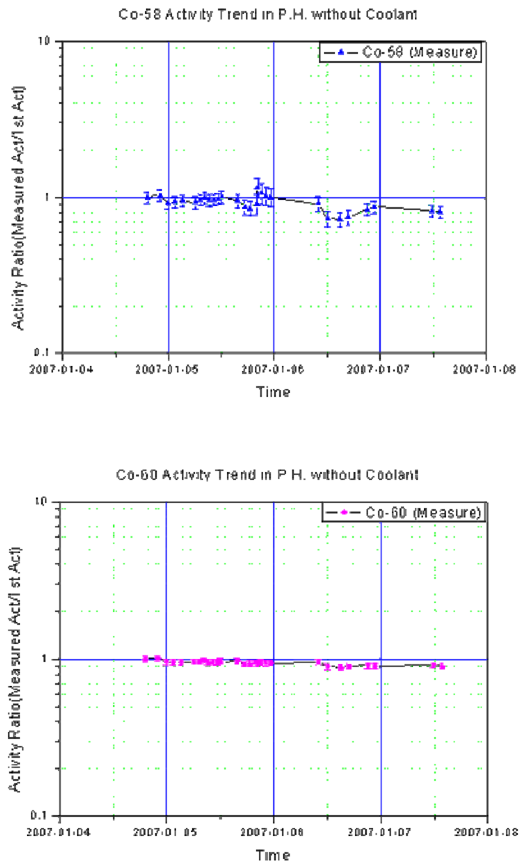

Figure 4. The trend of activity ratio of SG channel head

3. Conclusion

To conduct successful shutdown chemistry, it is important to monitor and control transports of crud during shutdown.

We found out that plant test such as rod drop tests can possibly cause thermal-mechanical release of particulates. Therefore it is recommended that the feasibility of scheduling rod drop tests at the beginning of cycle at Yonggwang be investigated.

The electronic dosimeters enabled us to easily monitor corrosion product transports by tracking dose rates variation in primary components during shutdown chemistry. We think that electronic dosimeters can provide significant information regarding changes in shutdown chemistry practices to help eliminate undesirable condition.

In addition, by using ISOCS device, we can follow the variation of activity of steam generator channel head during refueling outage 9 of Yonggwang unit 4. This measurement shows that shutdown chemistry is not effective for plant decontamination, so there is room for shortening outage schedule.

We are planning to apply these devices to additional PWR plants for optimizing shutdown chemistry practices in Korean PWR plants.